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Research Article

Sustainability Improvement of Ethanol Blended Gasoline Fuelled Spark Ignition Engine by Nanoparticles

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The sophisticated technology being used in automotive technology, as well as the increased use of vehicles, enables the engine to operate on a variety of alternative fuels. Natural or synthetic carbon-based connections are responsible for the formation of ethanol. They may be produced from a variety of sources, including agricultural feedstock, local crops, and even agricultural trash and waste products. Because they are in the form of a renewable resource, they may be employed in a variety of applications, including IC engines, where they can be used as fuel or as an addition, depending on their composition. It is possible to dramatically improve the performance of gasoline engines using a novel mix of nanoadditives, ethanol, and gasoline while simultaneously reducing the negative environmental impact. An ethanol-gasoline combination was used to power the engine in this work, which examined the effects of the alumina nanoaddition. Results reveal that thermal efficiency can be improved by up to 17% while fuel consumption can be reduced by up to 16% on a volume basis, indicating a considerable improvement over the basic engine. Also validated was a decrease in dangerous carbon monoxide emissions of as much as 14%, a reduction in unburned hydrocarbon emissions of 18.5%, and a significant reduction in oxygen of as much as 18%.

1. Introduction

As of right now, the vehicle industry is experiencing a boom in both demand and growth potential. The ever-increasing demand for automobiles increases our reliance on a wide range of fossil fuels. Fossil fuels' nonrenewability and growing pollution have sparked a hunt for an alternate source of energy. The growing population density of automobiles necessitates increased gasoline usage, which in turn reduces the supply and increases the price of the commodity. Therefore, it is vital to look for an alternative fuel that can efficiently replace the conventional gasoline without significant impact on the engine design and operation of the vehicle [1].

The inclusion of additional carbon group elements or the introduction of new alcohols is not a fresh concept. Alcohols are characterised by the polymerization of hydroxyl groups to carbon atoms. To put it another way, the C-H chain of conventional fuels may be changed as a consequence of the inclusion of these additives, leading in the formation of new polymer chains. Methanol and ethanol are the two most often used alcoholic fluids in internal combustion engines [2]. Finished additives and performance additives are the two types of fuel additives that may be used with gasoline. All petroleum refineries utilise finished fuel additives to satisfy and maintain finished fuel quality guidelines and regulations. Gasoline is often supplemented with performance additives in order to improve specific characteristics of the fuel or to provide new characteristics that are not already there [3]. The SI engine's combustion efficiency is improved and increased by adding the performance additive to the fuel. It also reduces the emissions from the cylinders. Among performance additives, oxygenated additives are mostly derived from biomass, a sustainable source of energy. Oxygenated compound performance additives are now being added to gasoline in order to minimise emissions and increase SI engine performance [4].

SI engine performance and emissions utilising ethanol-gasoline mixtures are affected by the air–fuel ratio. Using ethanol-gasoline mixes resulted in an increase in torque output, according to engine performance testing. In terms of heat use, however, there is little difference. With the addition of ethanol, CO and HC emissions were lowered. Emissions may be effectively decreased by utilising gasoline containing 10% ethanol, as shown in this research [5]. Nanoparticles have gained prominence in recent years as a result of their unique inherent properties, which have resulted in a decrease in emissions and an improvement in engine efficiency in the vast majority of applications. The density, viscosity, heat of vaporisation, volatility, flashpoint, and other characteristics of fuel may be changed by adding nanoadditives to it. Metallic nanocatalysts were used in base diesel or gasoline fuels in the early trials of the technology [6, 7].

Because of the oxygen present, ethanol burns cleanly and efficiently. Aside from its impact resistance and high latent heat of evaporation, ethanol is one of the alcohols that have lately been added to hydrocarbon fuels as an additive. The higher octane number of ethanol enables greater compression ratios in alcohol-powered engines, which improves thermal efficiency [8]. The impact of an alcohol catalyst in a spark-ignition engine was investigated, and it was discovered that the energy density of the mixed fuel decreased as the octane number increased. In addition to improving brake thermal efficiency, the use of ethanol may assist to minimise environmental pollution as well as save money on gasoline [9]. Various kinds of alcohol fuels have been studied in the literature for their impact on engine performance and emissions of harmful pollutants, according to what has been found. When utilised as fuel in internal combustion engines, alcohols with a higher octane number than gasoline emit lower quantities of pollutants than gasoline does [2].

In order to outperform standard gasoline in terms of performance and emission characteristics, it has been explored if an auxiliary addition of alumina nanoparticle to an ethanol mixed fuelled engine would be beneficial. One of the key goals of this study is to increase thermal efficiency while also reducing fuel consumption while also reducing dangerous emissions and increasing the ability of the air/fuel to burn when nanoinflated. The light-power gasoline engine was subjected to an experimental research. The concentration of alumina nanoadditives is controlled at two different flow rates of 10 ppm and 20 ppm on a constant 20% ethanol-blended gasoline (E20) fuel. The essential test runs were carried out under a variety of load settings ranging from zero to full load in order to assure the best possible performance and the lowest possible pollutant emissions.

2. Materials and Method

Flex-fuel has different minimum and maximum vapor pressure requirements. These requirements change depending on year of evolution [10]. "Alcohol" refers to any organic compound that has the hydroxyl functional group (-OH) attached to the carbon atom of the molecule. As a result of oxygen being present in the hydroxyl functional group, alcohols burn evenly and create a significant amount of smaller pollutants and fine particulate matter. Reduced emissions are made possible by lower molecular mass alcohols like ethanol and methanol, as well as their greater flame speed and the absence of the elements phosphorus and sulphur [11]. In addition, the stoichiometric ratio of ethanol and gasoline is smaller than that of gasoline and diesel. Many researchers [12–16] achieved better performance on the blends of E20. The same quantity of air may burn a greater volume of fuel using this method, while compared to gasoline use, a larger reduction in fuel consumption was seen when using 20% ethanol, according to testing results. This resulted in an increase in flame thrust and calorific value, as well as a mixing of the air and fuel, which led to better combustion than could be achieved with gasoline alone.

When compared to pure gasoline, methanol and ethanol have greater oxygen concentration (49.93% vs. 34.7%), which encourages a more thorough burning of the fuel and minimises hazardous exhaust emissions. To avoid engine knocking, the Research Octane Number of the mixtures of ethanol and methanol is greater. Fuel consumption is projected to be greater for both ethanol and methanol since their lower heating value is lower than that of pure gasoline. The volumetric fuel efficiency of both alcohol fuels is improved by the increased densities. Due to the greater flow resistance of methanol and ethanol at low temperatures, this may have an impact on automotive fuel injection systems [17].

As the concentration of nanoparticles increases, they are being driven to the liquid surface in order to become more

Table 1: Properties of gasoline and ethanol blend.

Sl No.	Property	Gasoline	Ethanol	E20	ASTM testing methods
1	Lower heating value (MJ/kg)	44.0	26.9	41.8	ASTM D240
2	Kinematic viscosity, at 20°C (cSt)	0.5	1.5	0.67	ASTM D445
3	Density, at 15°C (kg/m^3)	737	785	746	ASTM D4052
4	Flash point, (°C)	-40	14	29	ASTM D93
5	Research Octane Number, RON	90	115	96	ASTM D2699
6	Motor Octane Number, MON	82	100	83	ASTM D2700
7	Oxygen (%)	0	35	7	ASTM E385
8	Stoichiometric air/fuel ratio	14.5	8.9	13.3	ASTM D5291

closely associated. Because of the strong cohesive force between the molecules in nanoparticles, they have a higher surface tension than larger particles. The average distance between the nanoparticles and the fuel molecules is decreasing. It is possible to increase the surface tension of nanoparticles by using the Van der Waals force rather than electrostatic repulsion [18]. The surface tension of nanoparticles fluctuates depending on the size and quantity of nanoparticles present. In response to variations in the bulk density of nanoparticles, variations in the attraction force between the nanoparticles and the surface tension of the fuel are seen. Surface tension in nanoparticles increases in proportion to the size of the nanoparticles being studied. The presence of smaller nanoparticles increases the surface charge density of larger nanoparticles, and the reverse is true [19]. Because of their strong heat conductivity and mechanical properties, alumina nanoparticles may have an impact on the combustion of biodiesel. Alumina is toxicologically volatile and irritating to the respiratory system, making it a poor choice for industrial applications. It reacts fast with water, forming hydrogen as a result. Because of the differences in size and shape of alumina nanoparticles, the combustion of mixed nanoparticle fuels is affected. It is possible to separate water molecules into hydrogen and oxygen in this manner [20]. Table 1 presents the properties of gasoline-ethanol blended fuel.

2.1. Experimental Details. The performance and emission characteristics of an ethanol mix and an alumina blend were investigated using a single-cylinder, four-stroke, air-cooled, spark-ignition engine operating under incremental load in this research. The engine that was used in the test was manufactured in accordance with the specifications listed in Table 2. To perform this investigation, it was chosen to use a single-cylinder, four-stroke, air-cooled spark-ignition engine with a compression ratio of 5 : 1 and a peak output of 3 kW at an engine speed of 3600 rpm, as well as a single-cylinder, four-stroke air-cooled engine. The incremental load was altered as a result of the mechanical loading. Figure 1 depicts a schematic illustration of the use of a light-duty gasoline engine for transportation. It was first necessary to start the engine with gasoline, after which it was subjected to a series of tests until steady-state working conditions were established. The brake thermal efficiency, specific fuel consumption, hydrocarbon, carbon monoxide, and oxygen emissions were all tested. All of the test runs were done using weights that were proportional to the weight of the load. When utilising ethanol-blended gasoline with alumina enrichment, the techniques are quite similar to those described above. The nanoparticles were examined for two distinct levels of contribution of 10 ppm and 20 ppm.

Table 2: Experimental engine specification.

Parameter	Description
Engine type	Four-stroke, single-cylinder
Rate power	3.0 kW @ 3600 rpm
Displacement	197 cc
Bore and stroke	67 × 56 mm
Compression ratio	5 : 1
Cooling system	Air-cooled engine

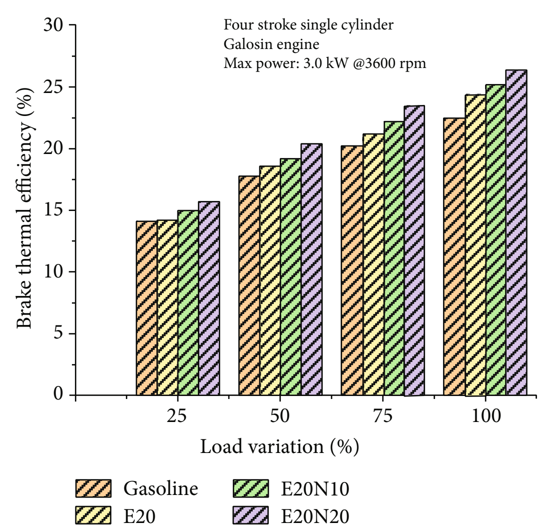

Figure 1: Impact of alumina on brake thermal efficiency on ethanol-gasoline engine.

The Crypton CGP-700 Analyzer was utilised to conduct the analysis of the emission measurement for this investigation. NDIR (Nondispersive Infrared) techniques are used in this completely microprocessor-controlled exhaust gas analyzer. CO, CO2, and hydrocarbons are all measured by this instrument. A second channel is supplied, which makes use of electrochemical oxygen measurement as well as a chemical sensor for nitrogen oxide detection. There is an

11-second reaction time to 95% of the final measurement while operating at operating pressures ranging from 750 to 1100 bar. It runs at a minimum flow rate of 5 litres/min. to ensure proper operation. During the experiments, the Crypton CGP-700 Analyzer was attached to the exhaust system, and the emission values were measured for a variety of fuel mixes under a variety of load circumstances [21–23]. The percentage of variance for each parameter may be calculated by comparing the results to those obtained from base fuel measurements.

The light-power gasoline engine was subjected to an experimental research with two concentration of alumina nanoadditives of 10 ppm and 20 ppm on a constant 20% ethanol-blended gasoline (E20) fuel. The fuel blend is prepared along with nanoadditives of alumina with 10 ppm and 20 ppm are represented at E20N10 and E20N20, respectively [24–26]. The essential test runs were carried out under a variety of load settings ranging from zero to full load in order to assure the best possible performance and the lowest possible harmful emissions.

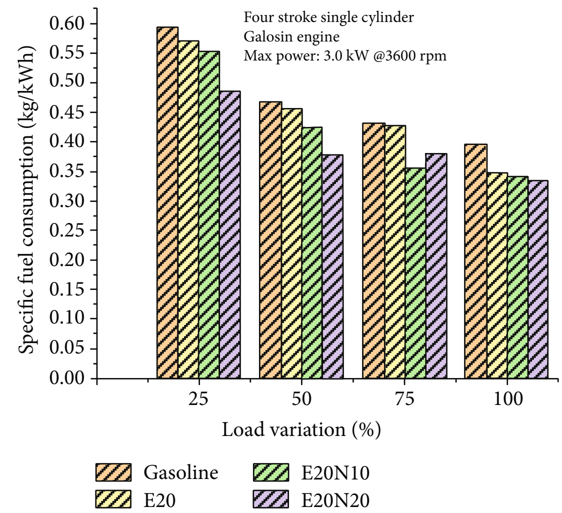

Figure 2: Impact of alumina on fuel consumption on ethanol-gasoline engine.

3. Results and Discussion

3.1. Brake Thermal efficiency. Brake thermal efficiency (BTE) of E20N10 and E20N20 was found to be 12% and 17% higher than gasoline when tested under maximum load as shown in Figure 1. At maximum load, 25.2% and 26.4% efficiency recorded for above blends. With the addition of oxygen, one may improve thermal conductivity by increasing the alumina concentration. When compared to the single fuel, all of the samples had greater brake thermal efficiency. Ethanol and gasoline mixtures containing cerium oxide nanoparticle additions are responsible for this. The fuel contains nanoparticles, which extend the combustion process and provide a more thorough burn. An oxygen supply from the nanoparticles increases efficiency. In addition, it has been shown that the improvement in efficiency typically rises with the nanoparticle dose level [5].

E20N20 blend recorded 8.2% of BTE, which is greater than E20 because of the enhanced oxygen and improved combustion rate caused by the high alumina component. A more thorough combustion is enabled by the increased oxygen concentration in both methanol and ethanol. As a result, heat loss in the combustion chamber is minimised, resulting in an increase in thermal efficiency from the use of fuel mixes containing ethanol. These enhancements will eventually lead to an increase in the thermal efficiency of the engine's braking system. As a result, it ensures that the H/C ratio of ethanol is higher than that of gasoline fuel, which is excellent for enhancing engine thermal efficiency. When fuel consumption and air ratios are raised, this results in a higher rate of combustion, which increases engine performance [27].

3.2. Specific Fuel Consumption. When comparing all test settings, ethanol-gasoline showed the lowest specific fuel consumption (SFC). Blend ratios increase with engine load, and as seen in Figure 2, the SFC drops as a result. Compared to gasoline, E20N10 and E20N20 blends achieved 13.6% and 15.4% lower fuel consumption, respectively, and E20 blends achieved 12% lower fuel consumption, respectively, when compared with gasoline. Ethanol has a lower calorific value per mass and volume than pure gasoline, which accounts for the little rise. So, in order to get the same braking performance as gasoline, the engine needs more methanol fuel. Other than that, methanol-gasoline fuel has a greater BSFC because methanol has a higher density; hence, more mass is injected into the engine per volume at the same injection pressure [17].

The characteristics of fuel mixing must be considered in order to understand this behaviour. Compared to pure gasoline, mixing fuel raises the engine's operating temperature when utilised in a spark-ignition engine. The increased speed of the flame is a result of improved combustion owing to higher octane and the effects of a higher flame burning rate and a shorter combustion duration generated by blending fuels. As the amount of mixed fuel increases, less fuel is used during the combustion process, while heat transfer losses are decreasing at the same time.

3.3. Exhaust Gas Temperature. At the maximum load, blends of ethanol E20, E20N10, and E20N20 show 3%, 7.3%, and 11.6% increase of exhaust temperature as shown in Figure 3. As a result, EGT values have decreased as a result of increased combustion reaction and increased concentration of ethanol within the binary mix, which has led to a decrease in EGT values. Because of its higher LHV feature, ethanol had a substantial cooling effect on the combustion chamber temperature of the gasoline engine that was being evaluated, particularly near the end of the induction process. Accordingly, as a last point of reference, it is feasible that a significant decrease in the EGT may be attributable to the causes that were mentioned above. Because of its natural oxygen atoms in its molecular structure, ethanol exhibits more advanced physicochemical properties than typical gasoline fuel, even if it takes longer to ignite than other alcohol-based fuel options. Higher-order alcohol/gasoline mixes may

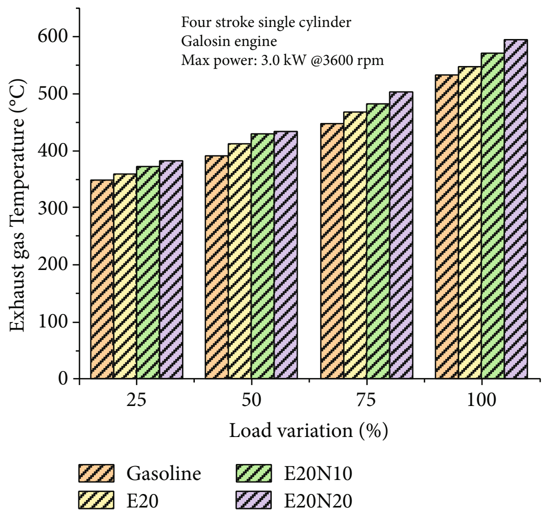

Figure 3: Impact of alumina on exhaust gas temperature on ethanol-gasoline engine.

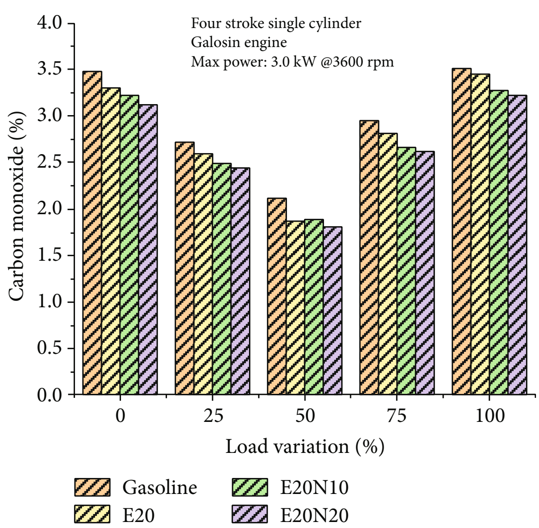

Figure 4: Impact of alumina on carbon monoxide emission in ethanol-gasoline engine.

thus reduce exhaust heat more effectively than straight gasoline in the SI engine being tested [28].

3.4. Emission Characteristics

3.4.1. Carbon Monoxide Emission. At the maximum load, blends of ethanol E20, E20N10, and E20N20 show 2%, 6.5%, and 8.2% reduction of carbon monoxide compared to gasoline as shown in Figure 4. Compared to gasoline, E20N10 and E20N20 blends achieved 10.8% and 14.5% lower CO, respectively, and E20 blends achieved 11.5% lower carbon emission when compared with gasoline. The usage of ethanol has resulted in a significant reduction in CO content, which is attributed to the presence of more oxygen molecules in the ethanol structure. The nanocomposite particles, on the other hand, may both boost the air–fuel homogeneity as a result of the lower viscosity of a mix and improve the burning rate and oxidation process. The effective combustion of the uniform charge of the nanoinvolved mix results in more and more oxidation of CO to CO2, resulting in a decrease in the quantity of CO released into the atmosphere [6].

It is easier to ignite the stratified blending fuel ratio because it is closer to the cold cylinder wall and the sparking plug, which leads the flame propagation to quench closer to the plug and ignites the blend more quickly. On the other hand, having a wide lean burn limit both raises the temperature of the combustion process and accelerates the spread of the flame. This results in lower CO emissions due to the fact that the subsequent phase of the combustion process may release heat more quickly and for shorter amounts of time [14]. Using blended fuels, it may be seen that the concentration of carbon dioxide is decreased. As a result of having a low carbon to hydrogen ratio when mixing fuel, it also burns more effectively when the mixture is more homogeneous, resulting in a reduction in CO2 emissions [27].

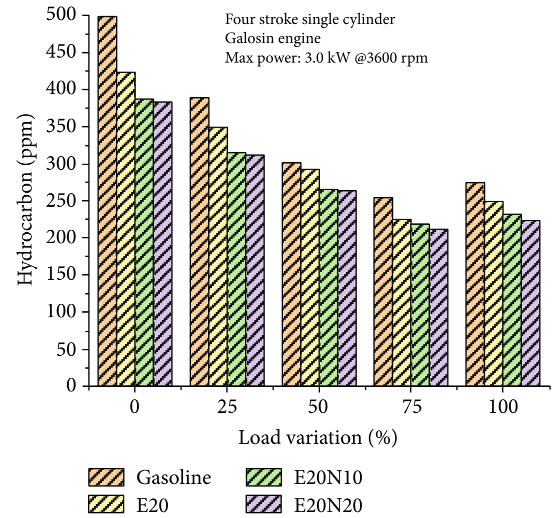

Figure 5: Impact of alumina on hydrocarbon emission on ethanol-gasoline engine.

3.5. Hydrocarbon Emission. When loaded to their full capacity, ethanol blends E20, E20N10, and E20N20 exhibit reductions in hydrocarbon emissions of 9.1%, 15.6%, and 18.5% when compared to gasoline as shown in Figure 5. When compared to gasoline, E20N10 and E20N20 blends produced 19% and 20% fewer hydrocarbon emissions, respectively, while E20 blends produced 11.5% lower carbon emissions. The absence of oxygen, the low temperature, and the heterogeneity of the mixture are the primary reasons of full combustion failure and the creation of HC [12]. The quantity of hydrocarbons released is proportional to the amount of ethanol that is consumed. The higher the ethanol percentage, the more homogeneous the mixture becomes, which in turn leads to lower HC emissions and improved combustion. Combining various kinds of fuel not only enhances the effectiveness of the combustion process but also speeds up the process of wall quenching. As the speed of the engine increases, an enrichment of the mixture takes place, which results in increased HC emissions [15]. When

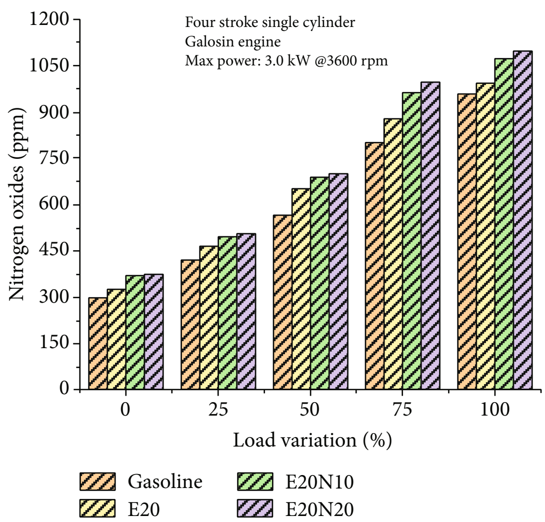

Figure 6: Impact of alumina on nitrogen oxide emission on ethanol-gasoline engine.

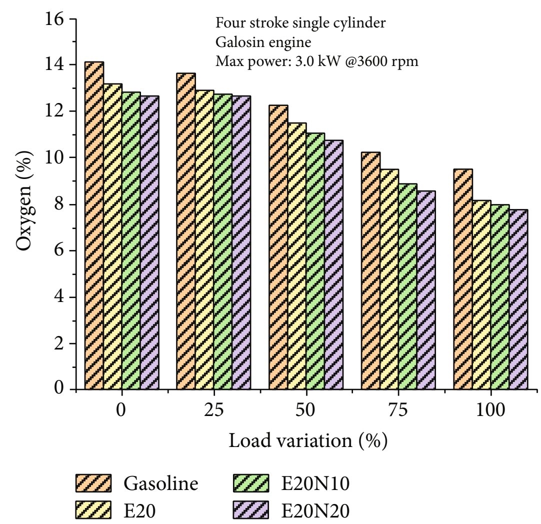

Figure 7: Impact of alumina on oxygen emission on ethanol-gasoline engine.

the engine speed increases, the HC concentration decreases because of the longer valve overlap duration at low speed and this drop becomes more pronounced at higher speeds. The difference in hydrocarbon emissions is related to the operation of the brake meaning effective pressure, which increases the cylinder temperature and hence improves combustion, resulting in a drop in hydrocarbon emissions [13].

3.5.1. Nitrogen Oxide Emission. Nanotechnology plays a key part in the release of oxygen from ethanol, which results in an increase in NOx emissions in the exhaust. Reversing the equilibrium in favour of the retrograde reaction is achieved by the nanoparticle's gradual breakdown of the created NOx bonds. It has been reported that the usage of metal additives, which are nanoparticles, may enhance combustion temperatures and, as a result, NOx emissions [6]. Figure 6 indicates that when the maximum load is applied, the ethanol mixes E20, E20N10, and E20N20 result in a 3.5%, 11.9%, and 14.4% rise in nitrogen oxide, respectively. E20N20 mix has also been shown to have peak emissions of 24% at half load condition.

Additionally, when engine speed increases, so does the concentration of nitrogen oxides (NOx). As opposed to blending fuel, NOx emissions were found to be greater at all engine speeds when using gasoline fuel. As the load grows, there is a corresponding increase in the consumption of fuel, which causes the temperature of combustion to rise. As a result, there is an increase in the quantity of NOx that is emitted into the atmosphere [13]. In addition, the increased cooling energy flow impact of mixed fuel, which slightly decreases cylinder gas pressure and the combustion time, is linked to this. In addition, delayed ignition timing may support lower NOx emissions to a higher extent without reducing the increased thermal efficiency, since hydrogen flame propagation is fast and permits stable combustion to take place continuously [29].

3.6. Oxygen Emission. The presence of oxygen is reduced by 14%, 16%, and 18.2% when the maximum load is applied to blends of ethanol E20, E20N10, and E20N20 compared to pure gasoline at the highest load as shown in Figure 7. E20N20 blends produced 9.5% fewer oxygen emissions as compared to E20 blends, owing to improved combustion characteristics. There is a possibility that enhanced oxygen emission was caused by the addition of alcohol to gasoline. This may be attributed, at least in part, to the naturally high oxygen concentration of the alcohol. As a consequence of this, a greater quantity of oxygen is discharged into the environment as a result of the higher alcohol blend ratio in the blend. This is due to the fact that the blend contains more alcohol [16]. Since oxygenated additives and ethanol accounted for a greater proportion in this mix than gasoline, O2 emissions were noted to be higher than those of gasoline operation [28].

4. Conclusion

The negative impacts of conventional engine fuels on climate change and global warming have created a situation in which there is intense competition to develop an alternative fuel that is more environmentally friendly and nonharmful to the environment. It was discovered that mixing alcohol fuel with engine-designed gasoline was quite practical. The light-power gasoline engine was subjected to an experimental research. The concentration of alumina nanoadditives is controlled at two different flow rates of 10 ppm and 20 ppm on a constant 20% ethanol-blended gasoline (E20) fuel. Brake thermal efficiency of E20N10 and E20N20 was found to be 12% and 17% higher than gasoline when tested under maximum load. Compared to gasoline, E20N10 and E20N20 blends achieved 13.6% and 15.4% lower fuel consumption, respectively. On the emission, E20N10 and E20N20 blends achieved 10.8% and 14.5% lower CO, respectively, and 19% and 20% fewer hydrocarbon emissions, respectively, while E20 blends produced

11.5% lower carbon emissions when compared with pure gasoline. The presence of oxygen is reduced by 14%, 16%, and 18.2% when the maximum load is applied to blends of ethanol E20, E20N10, and E20N20 compared to pure gasoline at the highest load. As a result of this, researchers must find a way to lower the cost of producing ethanol from renewable feedstock's so that it may be used in IC engines at a lower cost than gasoline. Rather of relying on imported pure gasoline, nations will be able to produce an alternative fuel additive and reduce their need on it. Ethanol is a renewable, domestically produced fuel that can outperform gasoline due to its higher octane rating. The creation of ethanol in rural areas provides desperately needed jobs. In transportation, ethanol can be used instead of fossil fuels. It holds great promise for reducing carbon emissions from transportation and improving the environment.

Data Availability

The data used to support the findings of this study are included in the article. Should further data or information be required, these are available from the corresponding author upon request.

Disclosure

This study was performed as a part of the Employment Hawassa University, Ethiopia.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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